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Energy Storage For Wind Energy Integration and Smart Grid

Net Zero Energy Installation and Deployed Bases Workshop

Frank Novachek
Director, Corporate Planning
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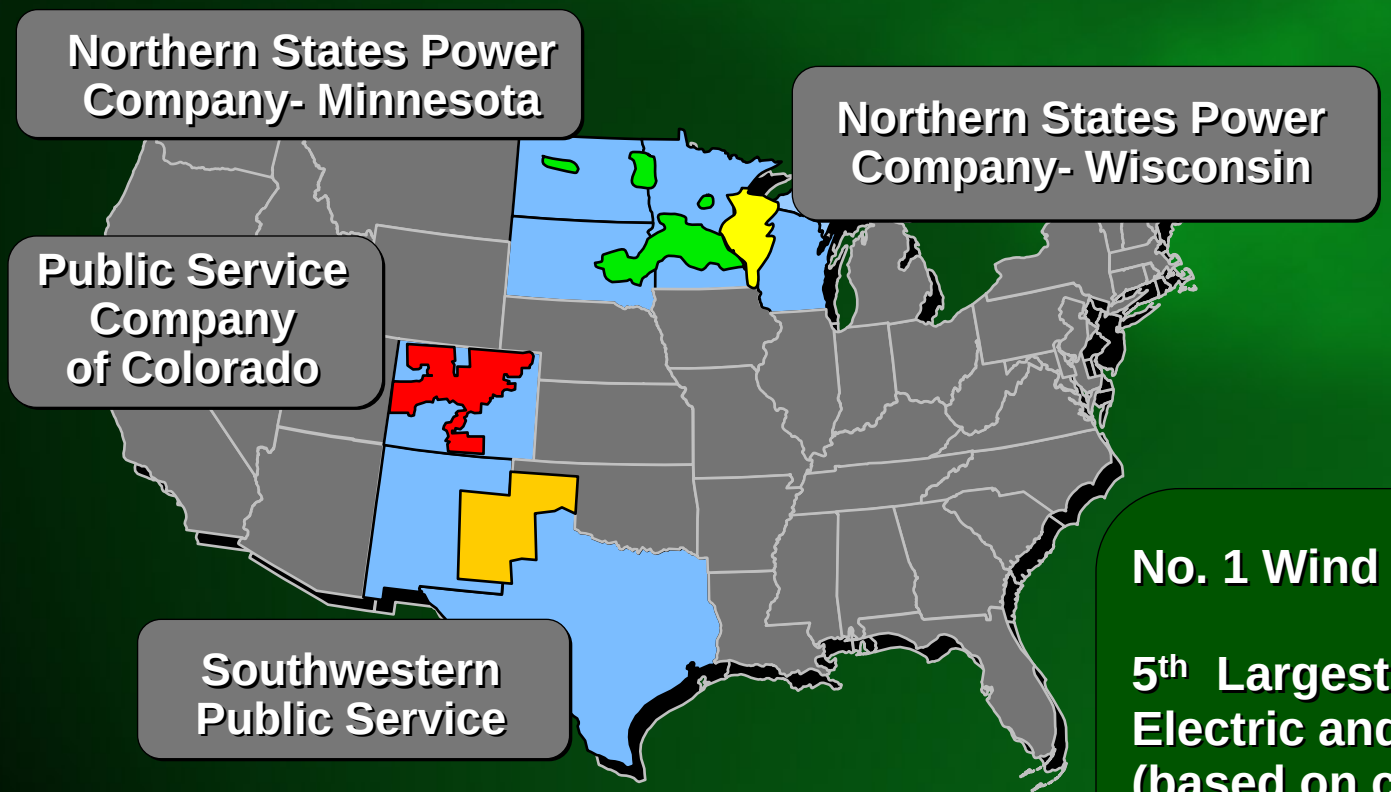
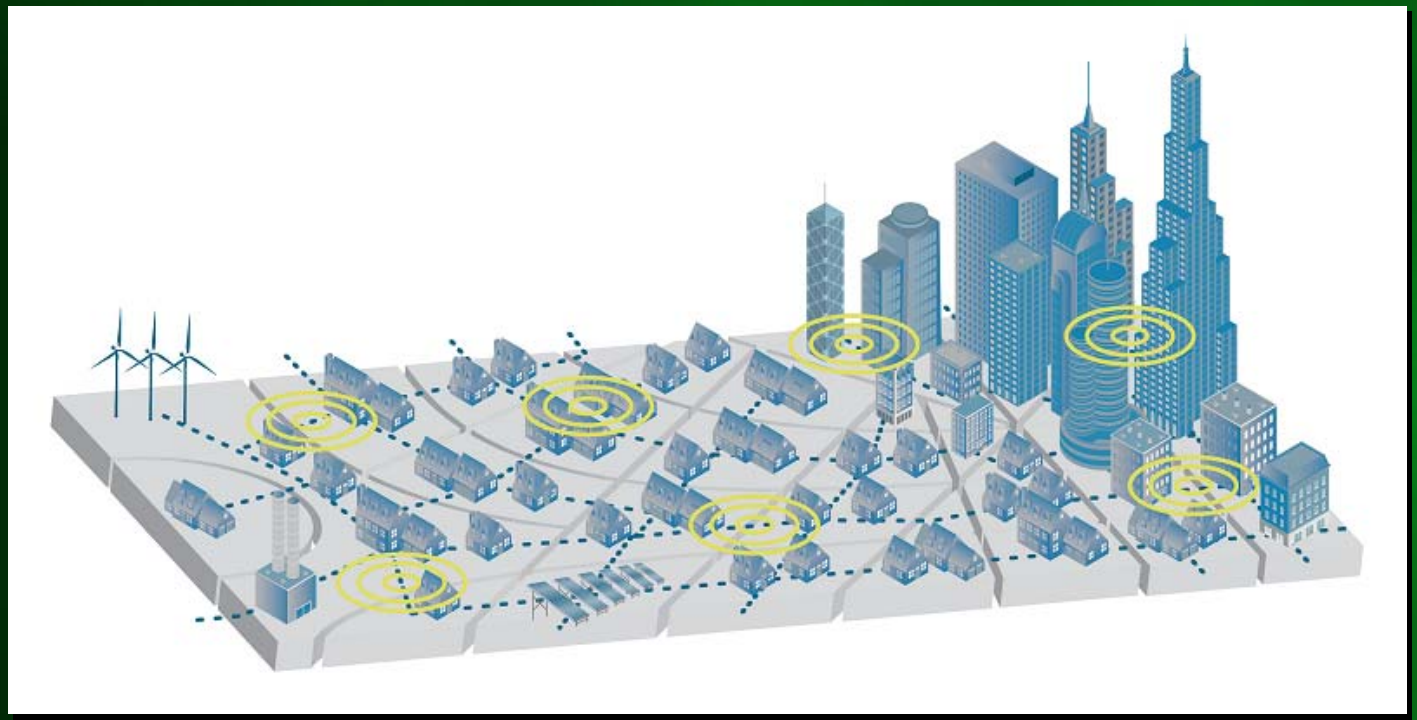


No. 1 Wind Energy Provider

5th Largest Combination Electric and Gas Utility (based on customers)

Environmental Innovator

An Integrated Energy System



- Incorporates entire energy pathway, from generation to customer
- High-speed, near real-time, two-way communications
- Sensors enabling rapid diagnosis and corrections
- Dispatched distributed generation
- Energy storage

Areas of Economic Value For Energy Storage

- **Delay renewable energy delivery**
  (e.g. Time shifting, baseload bottoming avoidance, smoothing, ramp rate control)
- **Reduce power plant cycling and availability requirements** *(e.g. O&M and capital savings, spinning reserve)*
- **Support transmission and distribution grid systems**
  (e.g. Ancillary services, wind curtailment avoidance, peak shaving, and power quality)
- **Avoid hidden dispatch/integration costs**
- **Hedge natural gas prices**
- **Achieve long-term environmental benefits**

Wind-To-Battery Project

1 MW NaS Battery System

- Delivers 1 MW for 7 hrs
- Power Conditioning Equipment
- 175 kW backup power
- Wind farm/grid interconnection
- Local and remote communication and control

Two Phases of Study

- Understand how system could optimize wind farm economies
- Understand how system could optimize utility integration of wind resources

Luverne, MN

Testing Modes

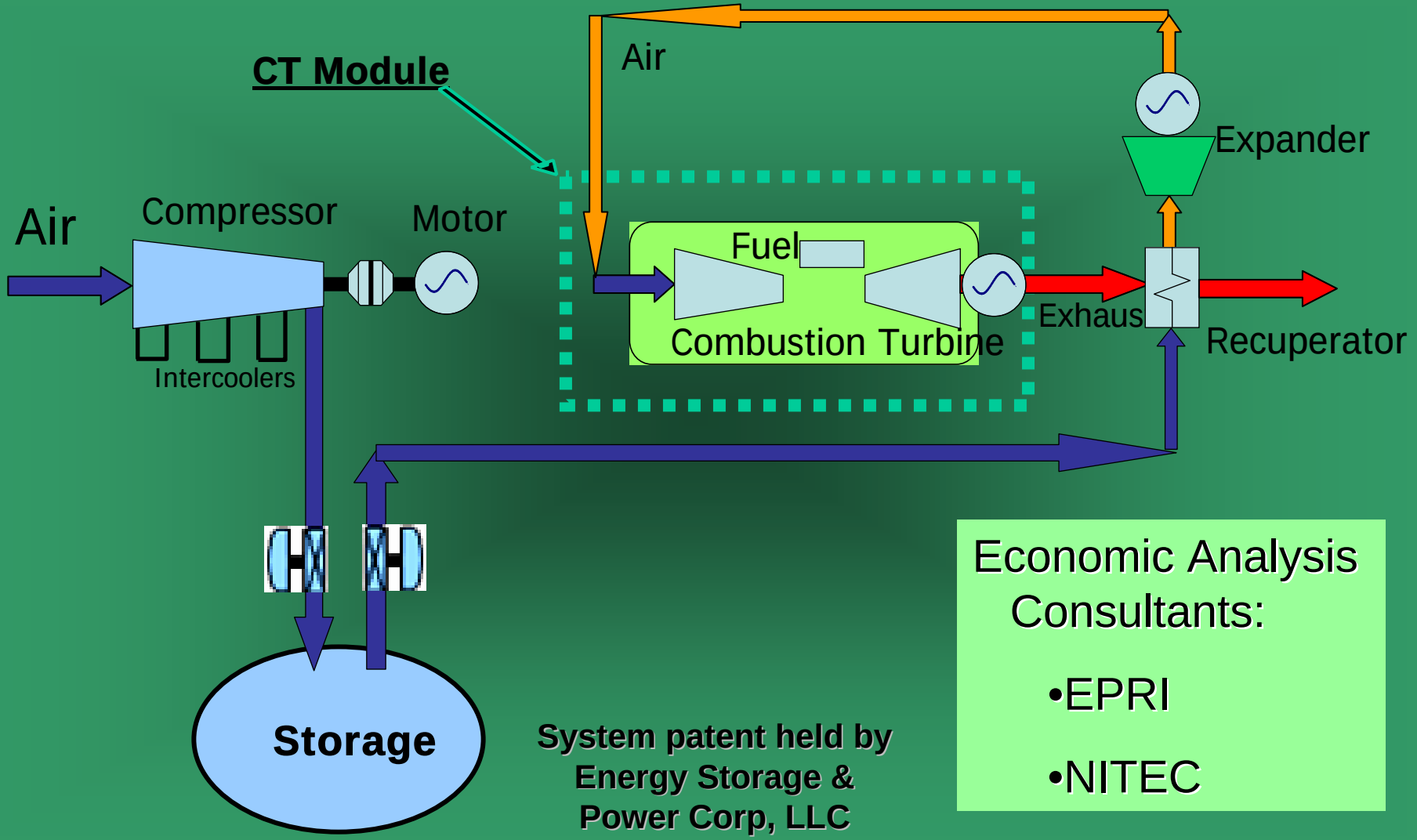
Mode of Operation	Control Driver(s)
Basic Grid Support: Wind	**Wind Farm Output** (Charging) **+Time of Day** (Discharging)
Basic Grid Support: Wind + Grid	**Wind Farm Output + Grid When Needed** (Charging) **and Time of Day** (Discharging)
Economic Dispatch	**Operating System Price Signals** (Charging and Discharging)
Frequency Regulation	**Operating System Regulation** (Charging and Discharging)
Wind Smoothing – Ramp Rate Control	**Wind Farm Output + Wind Farm Output Rate of Change Limiter** (Charging and Discharging)
Wind Leveling – Steady Output Control	**Wind Farm Output** (Charging) **and Fixed Set Point for Combined Output** (Discharging)

Wind & Solar Hydrogen Energy Storage

Adding hydrogen production to wind and solar value chains can deliver multiple-market services:

- Bulk electric energy (existing)
- Stored electric energy:
  - Renewables Shock Absorber
  - Wind Energy Time Shift
- Green fuel for fuel cell vehicles

Compressed Air Energy Storage (CAES) Concept



System patent held by Energy Storage & Power Corp, LLC

Economic Analysis Consultants:

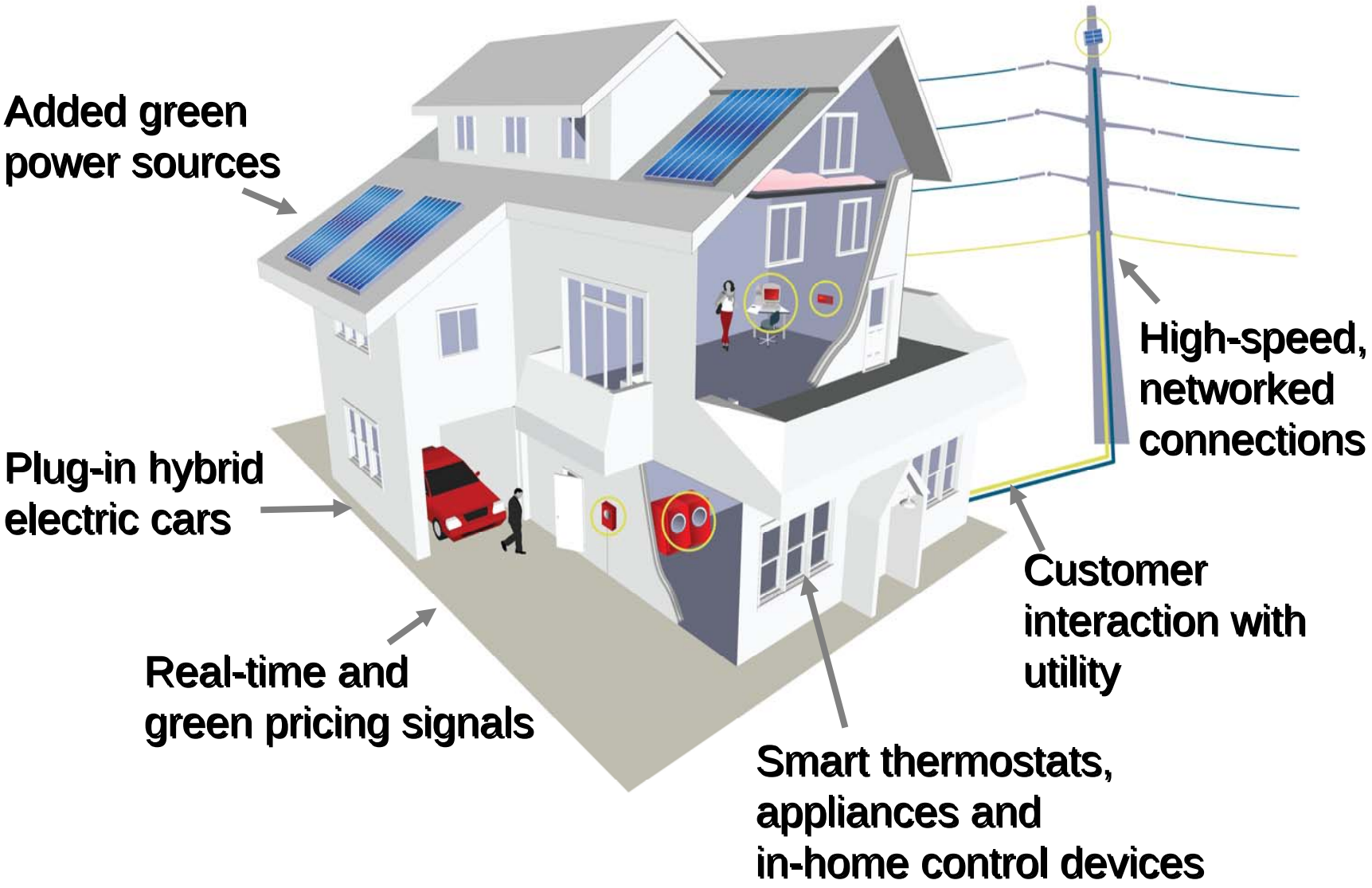
- EPRI
- NITEC

SmartGridCity™ - *Boulder, Colo.*

"An international showcase of smart grid possibilities… a comprehensive demonstration of an intelligent grid community"

- Bringing the vision to life
- Leverage the best talent
- Build skills and experience
- Test technology and processes
- Prove benefits

The Smart Home



SmartGridCity And The Future

- SmartGridCity will test how smart grid can deliver
- Future is unknown
  - Information unleashes power of innovation
  - Transforms utility in ways we cannot imagine
- Stronger energy system
- More choice and opportunity
  - Customers
  - Shareholders
  - Employees

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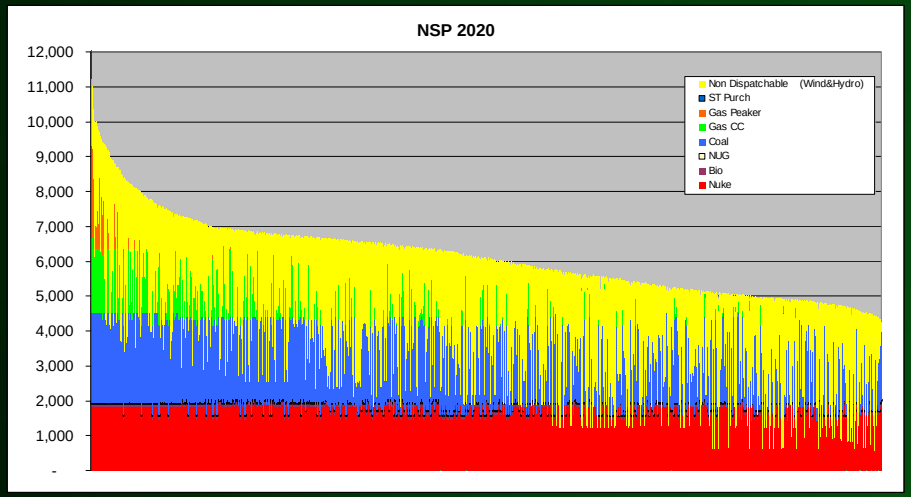
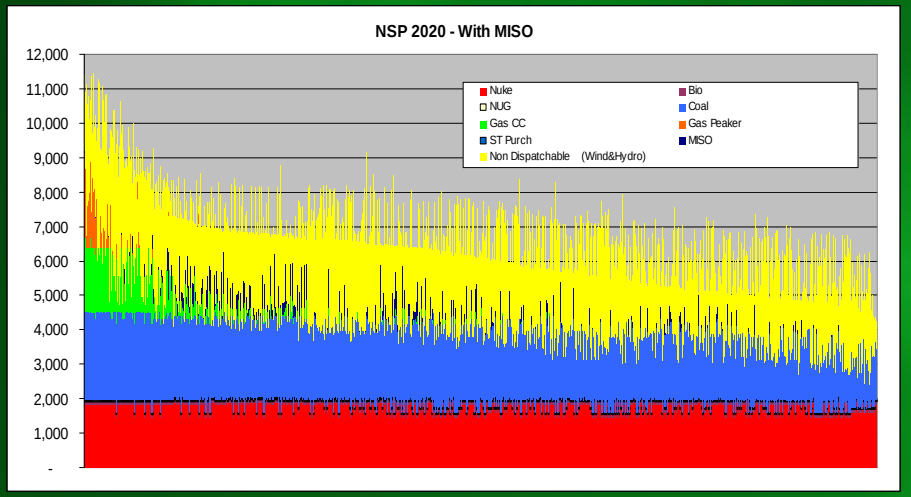
Storage as Shock Absorber to Mitigate Baseload Bottoming?



NSPM System: Effect of Absorbing 3,800 MW of Wind Energy



NSPM System With MISO: Effect of Absorbing 3,800 MW of Wind Energy

Hidden Dispatch/Integration Costs